Joining Technology of Very Large Floating Structures

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1.INTRODUCTION

Recently, the advantage of Mega-Float (Very Large Floating Structures) attracts great deal of public attention. In order to construct Mega-Float, however, some issues remain. Because it is too large to build at any building dock or other site on the ground, the construction by joining floating units together on the sea is inevitable. Some advanced technologies for constructing operations on the sea are necessary, such as maintaining precise measurement of each unit, joining units in waves and under-water welding techniques.

Technological Research Association of Mega-Float (TRAM) has developed these construction technologies since 1995, and established them through construction of two experimental floating models, called phase- I and phase- II model[1]. Figure 1 shows phase- II model (Floating Airport Model; 1000m × 120m × 3m), and in this case it takes only one month from start of mooring of first unit to completion of welding of all units. In this paper, we show general aspect of these construction technologies.

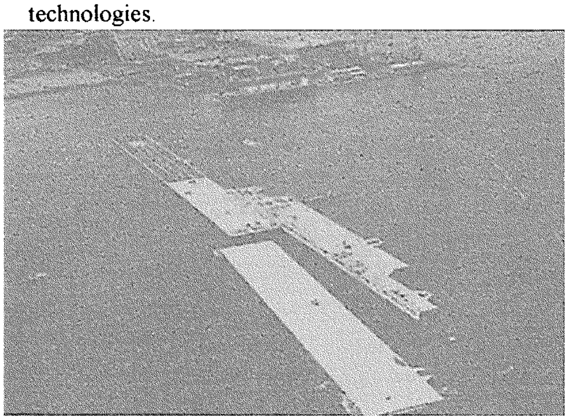


Figure 1 Construction of Floating Airport model (phase- II model)

2.Key Issues for Joining Floating Structures on the sea

When we construct Mega-Float, we have to join many floating units together on the sea. In this case, there are some issues to be solved. Especially, items described below become significant issues for construction on the sea. (Refer to Figure 2)

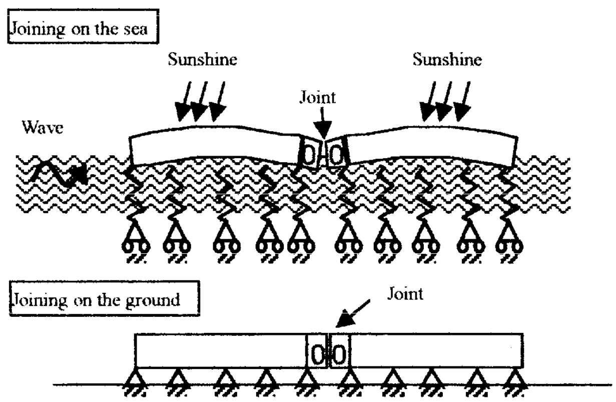


Figure 2 Joining condition on the sea and on the ground

(1) Control of relative motion between floating units caused by wave
(2) Estimation of deformation
- Thermal deformation caused by sunshine
- Welding deformation

(3) Under-water welding technique
(4) Measuring technique

We have solved these issues during construction of two experimental floating models, phase- I and phase- II. We outline these issues and solution in the following chapters.

3.Control of relative motion between floating units

When we join two floating structures together on the sea, we must bring them near mutually. In this case, these floating structures are moving independently because of wave. Therefore, we control the relative motion between floating units by using some equipment, such as jack, turnbuckle, wooden wedge and etc. And gradually the motion becomes small. In other words, two floating units become mechanical joining condition. After that, the joint is restricted by strong-backs or fitting pieces, so that any crack dose not occurs during following welding. This process is shown in figure 3.

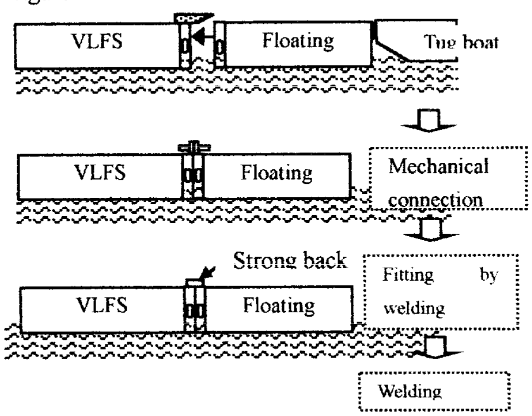


Figure 3: Typical sequence of joining floating units

Estimation of the relationship between the value of relative motion and joint force during joining operation is very important for providing joining procedure and design of joining equipment. This relationship can be sketched as Figure 4[2].

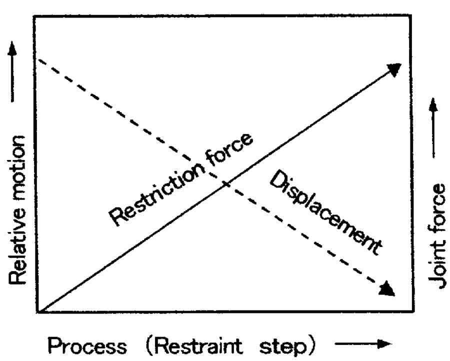


Figure 4 Relative motion and joint force as joining process

During construction of phase- II model, we carried out some experiments for confirming this relationship. The experimental results were compared with the analyzed results by newly developed methods. Example of these results is shown in figure 5[3].

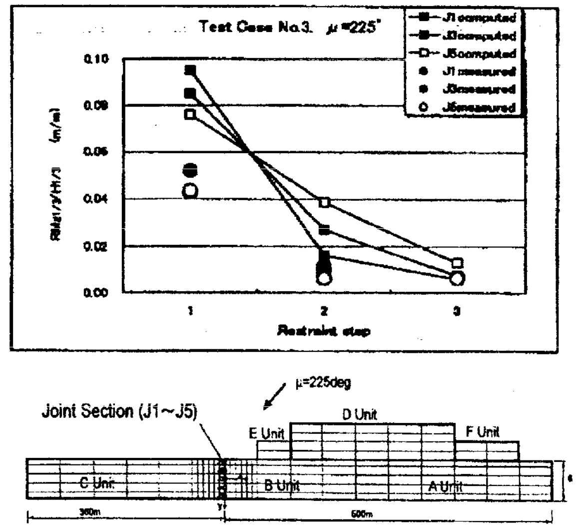


Figure 5 Comparison of measured and computed relative vertical motions as joining procedure

4.Estimation of deformation

4.1Thermal deformation caused by sunshine

As shown in figure 2, the floating structure on the sea is deformed easily by thermal distribution in the structure. At day time, the deck plate of the floating structure is heated by sunshine and the temperature of it is about 30℃ higher than bottom plate. This distribution of temperature causes thermal deformation of the floating structure. This thermal deformation causes not only geometrical inaccuracy of the floating structure but also wide opening between bottom plates of floating units. Therefore, precise estimation of this thermal deformation is very important for joining operation. In case of construction of phase- II model, we estimated this thermal deformation by 3D FEM analysis. And we made sure that the values of estimation by using FEM analysis agree well with experimental data. Example of analyzed result by FEM is shown in figure 6.

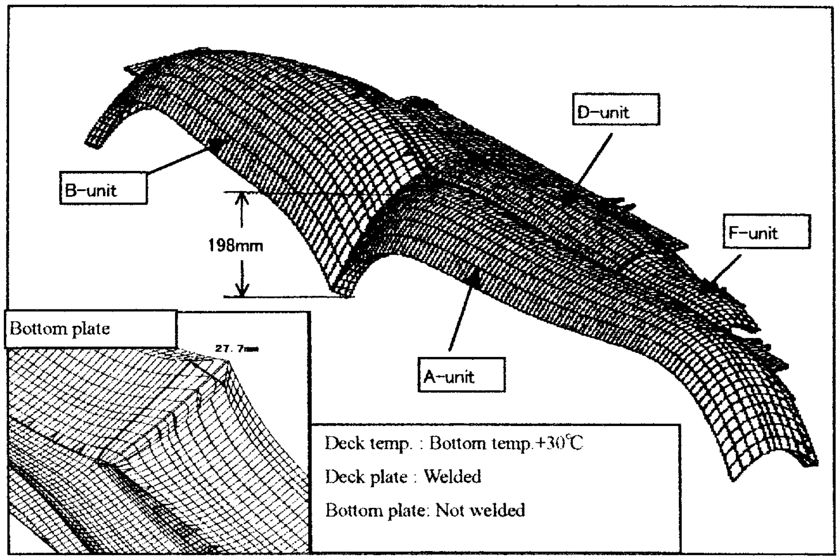


Figure 6 Estimation of thermal deformation during joining operation of A-unit analyzed by FEM

4.2 Welding deformation [4]

In case of constructing Mega-Float, many floating units shall be joined together asymmetrically, because joining operation of floating units shall be started from the side of mooring system. Therefore it is necessary to solve particular problems concerning welding deformation as shown in figure 7.

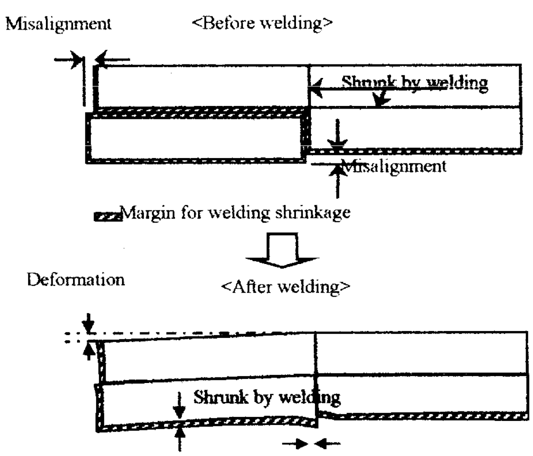


Figure 7 (a) :Misalignment and welding deformation caused by welding shrinkage

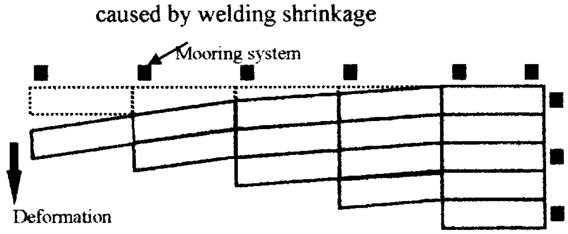
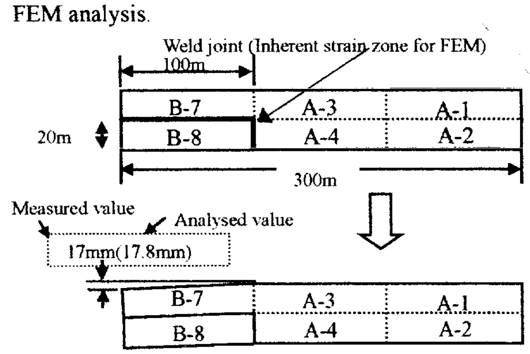


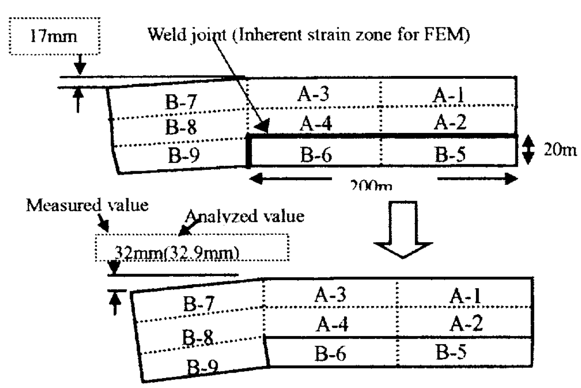
Figure 7 (b) :Deformation of VLFS caused by welding of floating units

Figure 7: Welding deformation of VLFS

During construction of the phase- I model, we measured the value of welding shrinkage and welding deformation, and we made sure analyzed values by FEM agree well with measured values of welding deformation as shown in figure 8. Therefore, precise estimation of welding deformation for Mega-Float is possible by using FEM analysis.

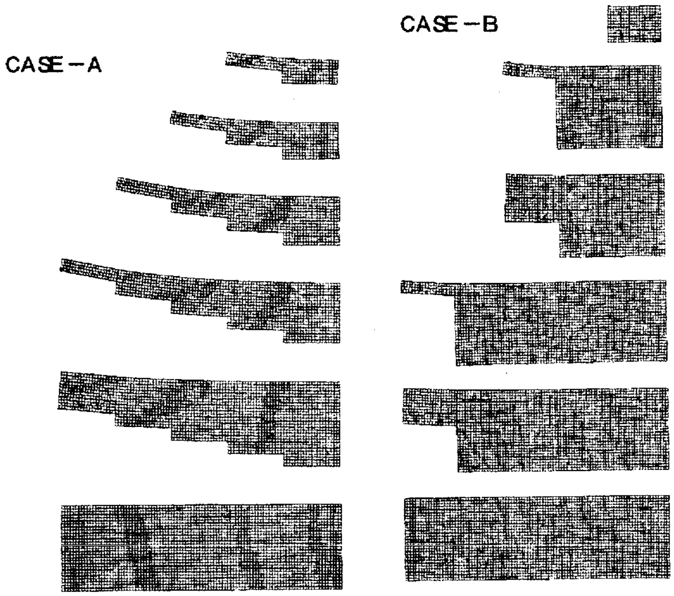


(a) Deformation caused by welding of B-8 unit



(b) Deformation caused by welding of B-5 × B-6 unit

Figure 8: Welding deformations of the large floating model



CASE-A

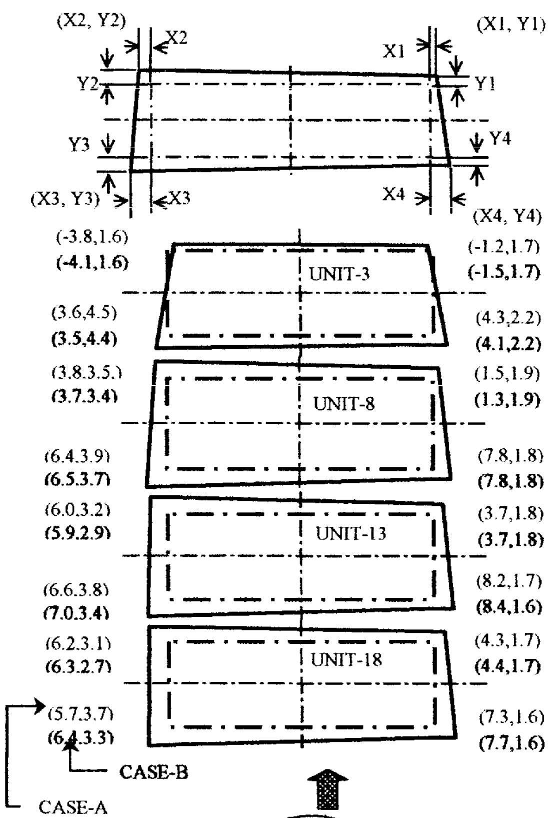
15	10	6	3	1
20	14	9	5	2
25	19	13	8	4
29	24	18	12	7
32	28	23	17	11
34	31	27	22	16
35	33	30	26	21

CASE-B

29	22	15	8	1
30	23	16	9	2
31	24	17	10	3
32	25	18	11	4
33	26	19	12	5
34	27	20	13	6
35	28	21	14	7

Joining sequence

Figure 9 Example of estimation of shape of floating structure during construction



UNIT-5	UNIT-4	**UNIT-3**	UNIT-2	UNIT-1
UNIT-10	UNIT-9	**UNIT-8**	UNIT-7	UNIT-6
UNIT-15	UNIT-14	**UNIT-13**	UNIT-12	UNIT-11
UNIT-20	UNIT-19	**UNIT-18**	UNIT-17	UNIT-16
UNIT-25	UNIT-24	UNIT-23	UNIT-22	UNIT-21
UNIT-30	UNIT-29	UNIT-28	UNIT-27	UNIT-26
UNIT-35	UNIT-34	UNIT-33	UNIT-32	UNIT-31

Figure 10 Initial unit shapes provided by FEM analysis

In order to minimize geometrical inaccuracy and misalignment among units of Mega-Float, "initial shape including margin for welding shrinkage" and "placing position" of each unit are primary procedures. Therefore, we try to provide these procedures by using FEM analysis, so that Mega-Float is shaped into designed shape after welding of all floating units. Example of the results by FEM analysis is shown in figure 8 -10.

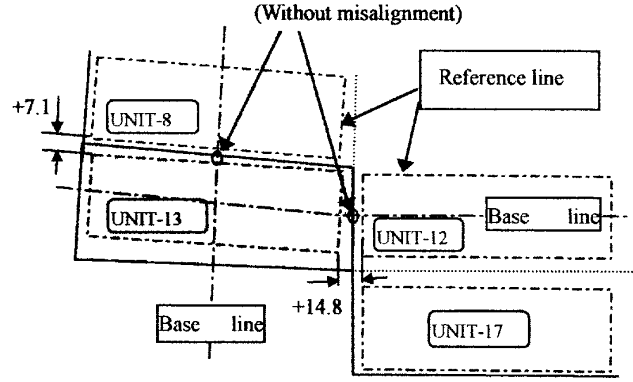


Fig.11 Positioning of newly joining unit (UNIT-13)

5.Under-water welding technique [5]

5.1 Working space (Dry space)

When we join pontoon type floating units together, we have to weld the joint under sea surface. In this case, we must apply wet welding or drain the seawater around the joint. In case of constructing the experimental models, we applied some procedures for this welding as shown in figure 8.

For the welding of bottom plates, there are some issues to be discussed as follows, other than existance of water.

- Considering thermal deformation and thermal stress caused by sunshine, bottom joint have to be obtained enough strength in a short time (from the sunset to the sunrise).
- Considering motion of the groove of the joint caused by wave, the joint have to be restricted by strong-backs and fitting pieces. Therefore, it is difficult to apply automatic welding to this joint. And it takes more man-hours for fitting and welding of this joint than operation on the ground.

Considering these issues, for bottom joint, many workers have to be on operation in the same time and wide working space is necessary. Therefore, in case of constructing the experimental models, we provided working spaces inside of the models for most of bottom joints. For the joint of side shell, we provided working spaces both sides of the models using the dry chamber.

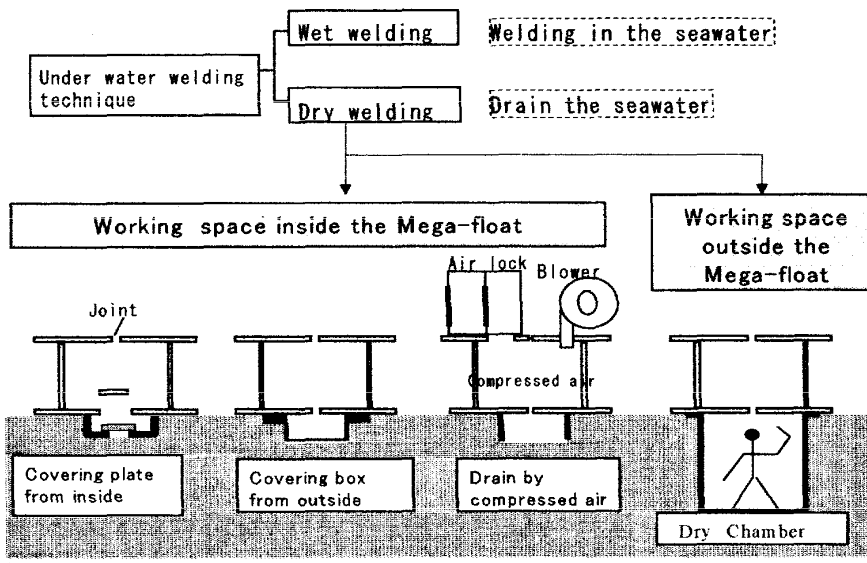


Figure 12 Working space applied to the experimental floating models

5.2 Welding procedure

Welding procedure for the bottom joint depends on position of working space. In case of using dry chamber outside of the bottom joint, we can provide welding from both side, but practically, we provided working space only inside of the structure, and in this case we have to weld from one-side. Figure 13 shows welding procedures applied for construction of the models. In case of welding of bottom joint of the floating units, we provide mainly working space inside of the modes, and applied one-side welding with backing strip. We think this welding procedure is best method for obtaining enough strength in a short time. But for some joints, considering fatigue strength of the joint, we applied welding procedure without backing strip.

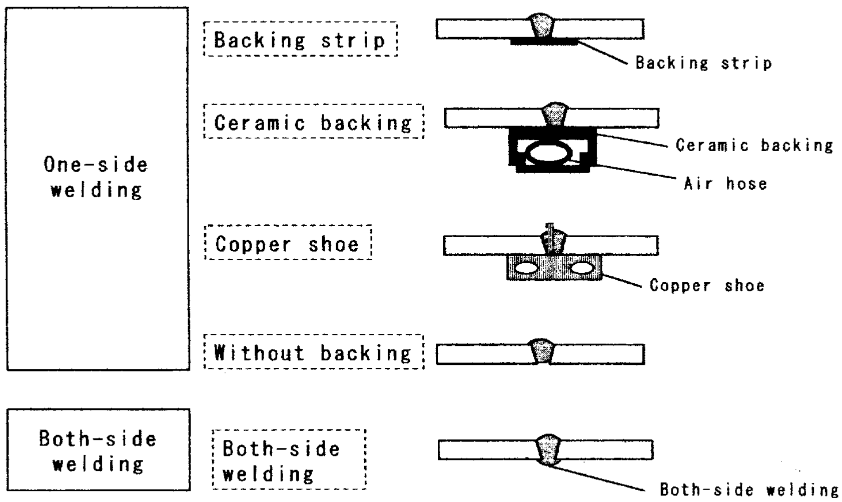


Figure 13 Welding procedures applied to experimental floating models

6.Measuring technology

For constructing Mega-Float, we have to consider particular issues about measuring technology as follows

- There is no reference points to be used for measuring on the sea.
- Size of Mega-Float is expanded with temperature change. (Position of the point on the Mega-Float is shifted with temperature change)
- Motion by wave

Therefore, in case of constructing the floating models, we applied some measuring methods as shown in Table 1. Finally, the Floating Airport Model (Phase-II model) shown in figure 1 has the 30mm in accuracy error for 1000m length.

Table 1

Object for measuring	Measuring method
Shape of floating unit at dry dock (Reference points and lines for positioning of floating unit on the sea)	3D Electro-optical Distance Measuring Instrument
Positioning of floating unit on the sea	Tape measuring of distance between reference points/lines 3D Electro-optical Distance Measuring Instrument GPS(global Positioning System)
Shape of the floating models	3D Electro-optical Distance Measuring Instrument GPS

7.Summary

In case of constructing Mega-Float, there are some particular issues as follows.

- Control of relative motion between floating units
- Estimation of deformation
- Under-water welding technique
- Measuring method

We have solved these issues during construction of two experimental floating models, and established construction technologies of Mega-Float.

References

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[2] S.SHIMAMUNE et al "Afloat Joining Method of Very Large Floating Structures and Response Analysis with Mathematical Modelling of Joint Mechanism" 14th Ocean Engineering Symposium, The Naval Architect of Japan

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[4] Y.YAMASHITA et al "Accuracy management of Very Large Floating Structures ", The proceeding of the Third International Workshop on Very Large Floating Structures (VLFS'99)

[5] Y.YAMASHITA "*Welding Engineering*" Jan 1998, Sanpo Publications, Inc.